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A high-resolution profile technique for CO_2 and H_2O at crop sites and implications for their flux source partitioning

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Motivation and Method

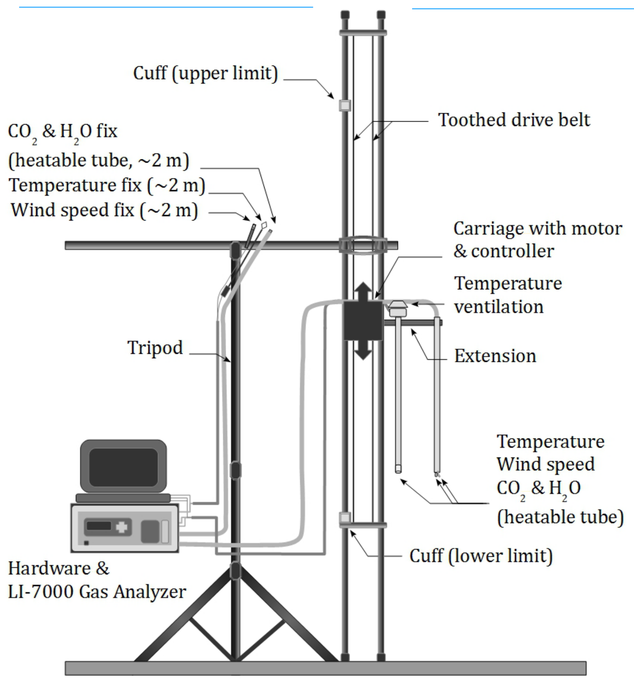

Fig. 1: Sketch of the measurement set-up

Inverting concentration profiles within the canopy has been suggested as a way of inferring the vertical source distribution and determining the flux partitioning between soil and vegetation (e.g. Santos et al. 2011). Previous attempts were mostly performed with a limited number of measurement heights and in high canopies such as maize or forest. We hypothesize that a high vertical resolution may improve the applicability, especially to low, dense canopies.

Fig. 2: Field test set-up at DE-RuS

We attached the end of a tube connected to a closed-path CO_2 and H_2O analyzer, as well as a finewire thermocouple and a hotwire anemometer, to an elevator continuously moving up and down between the soil surface and 2 m a.g.l., collecting about 50 profiles during 30 minutes at a logging frequency of 20 s^{-1}. The differential gas analyzer (Li-Cor Li7000) allows for a simultaneous second concentration measurement at a fixed height of 2 m. During the test phase in wheat and barley (spring 2015 to summer 2016), various improvements were introduced, including a fixed-height second wind speed and temperature measurement, ventilation for the moving temperature measurement, insulation and optional heating of the tubes.

The position of the elevator is logged and the delays of the other measurement channels, especially the tube delays for CO_2 and H_2O, are determined empirically by a hysteresis minimization algorithm. While the actual vertical and temporal resolution can be configured during data processing, we here present half-hourly mean profiles of 2.5 cm thick layer averages, together with first plausibility tests.

Results

… for vegetated and bare surfaces

Over bare soil, profiles match with Monin-Obukhov similarity theory (Fig. 3) and derived fluxes with Eddy-Covariance results.

In vegetation during daytime, wind speed u and temperature T profiles agree with expectations (Fig. 3), although a variety of T profiles was observed depending e.g. on sun angle. Profiles of H_2O indicate sources at the soil surface and in the canopy, and CO_2 profiles a soil source and canopy sink (Fig. 3). During the night, temperature and occasionally H_2O profiles are reverse, and both soil and canopy become a source of CO_2 (Fig. 4).

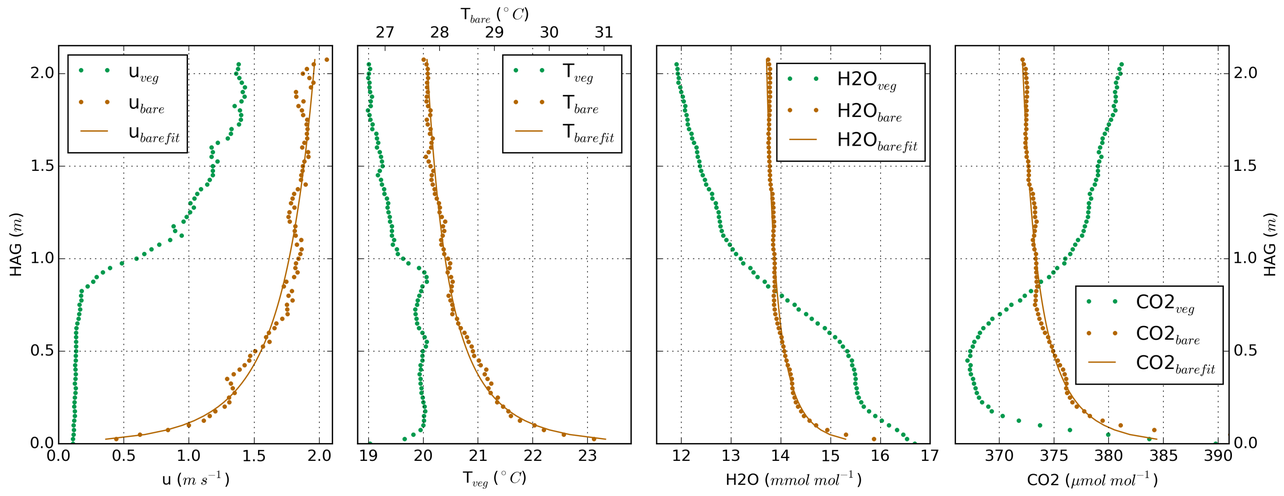

Fig. 3: Profiles on 2016-06-10 10:15 UT (barley, green) and 2016-07-18 16:15 UT (bare, brown) for wind u, temperature T, H_2O and CO_2 in moist air against height above ground (HAG). Lines indicate model profiles after fitting u_*, z_0, scalar fluxes, scalar surface values at z_{0T} (assuming z_{0T} = 0.1 z_0) and the Obukhov length L.

Outlook

Applying a dispersion matrix inversion (modified after Santos et al. 2011) yields first rough fits to the profiles, and magnitudes of evaporation, transpiration, soil respiration and canopy net primary production (Fig. 5). In a next step, the effect of turbulence parameter profiles and possible benefits of jointly available u, T, H_2O and CO_2 profiles will be examined.

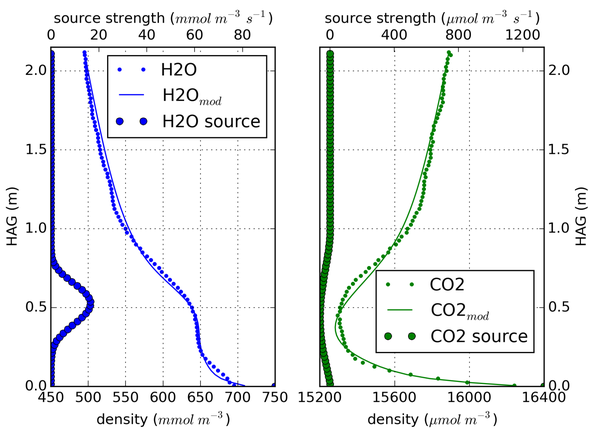

Fig. 5: Source and concentration profiles after inverting one soil source and three parameters of a vertical beta distribution of the canopy source/sink, 2016-06-10 10:15.

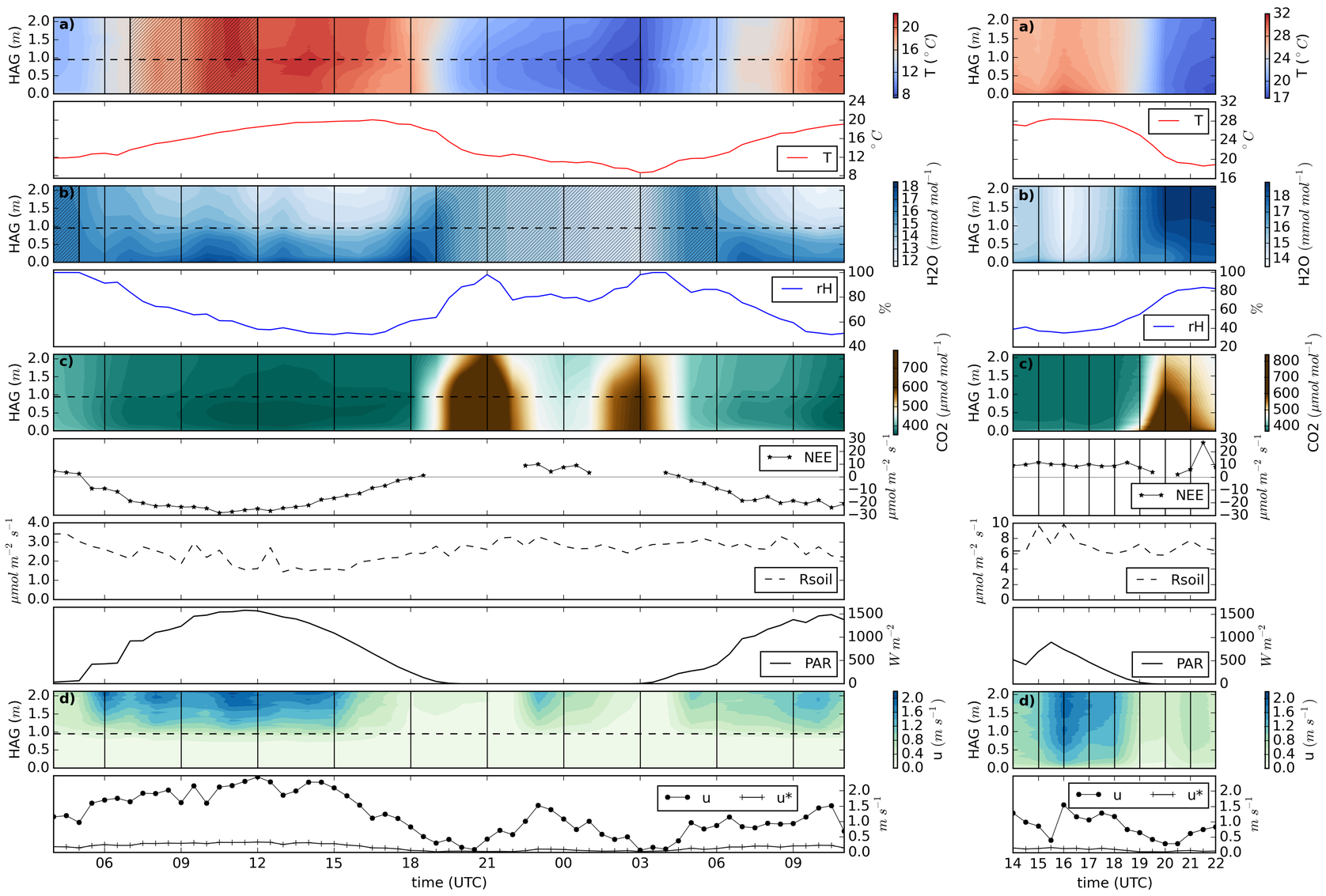

Fig. 4: 30-h measurement in barley starting 2016-06-09 (left) and 8-h measurement over bare on 2016-07-18 (right). Plots a-d refer to the profile system, line plots are based on eddy-covariance and soil respiration chamber measurements on the same field. Hatched areas refer to questionable data due to failure of thermocouple ventilation (T) and missing tube heating (H_2O).

References

Santos EA, Wagner-Riddle, C, Warland JS, Brown S, 2011: Applying a Lagrangian dispersion analysis to infer cabron dioxide and latent heat fluxes in a corn canopy. Agric. For. Meteorol. 151: 620-632.